NPS-09-96-011

Naval Postgraduate School
Monterey, California 93943-5138

SUMMARY OF RESEARCH 1995

Department of Operations Research

CAPT Frank C. Petho, USN
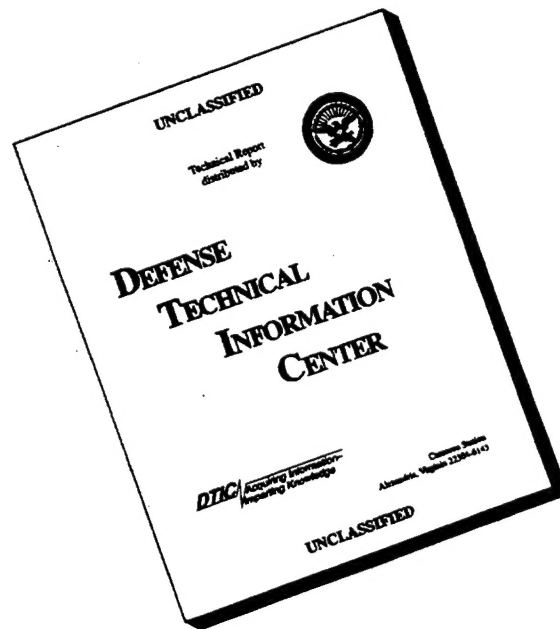### Chairman

Robert R. Read
Associate Chair for Research

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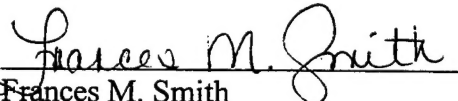### Monterey, California

Rear Admiral M.J. Evans
Superintendent

R. Elster
Provost

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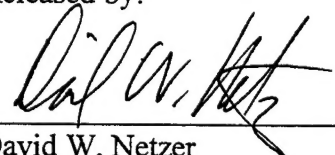
The report was prepared by:

Frances M. Smith
Frances M. Smith
Research Admin Assistant
Research Office

Reviewed by:

Danielle A. Kuska
Danielle A. Kuska
Programs Supervisor
Research Office

Released by:

David W. Netzer
David W. Netzer
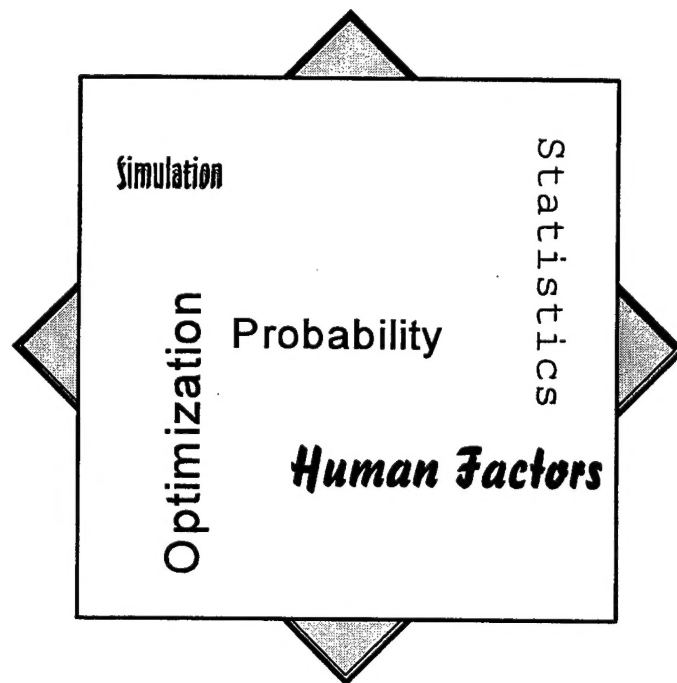Associate Provost and Dean of Research

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13. ABSTRACT (Maximum 200 words.)

This report contains **40** summaries of research projects in the Department of Operations Research which were carried out under funding of the Naval Postgraduate School Research Program. A list of recent publications is also included which consists of conference presentations and publications, books, contributions to books, published journal papers, and technical reports.

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Department
of
Operations Research

Simulation

Statistics

Optimization

Probability

Human Factors

THE NAVAL POSTGRADUATE SCHOOL MISSION

The mission of the Naval Postgraduate School is to provide advanced professional studies at the graduate level for military officers and defense officials from all services and other nations. The School's focus is to increase the combat effectiveness of the armed forces of the United States by providing quality education which supports the unique needs of the defense establishment.
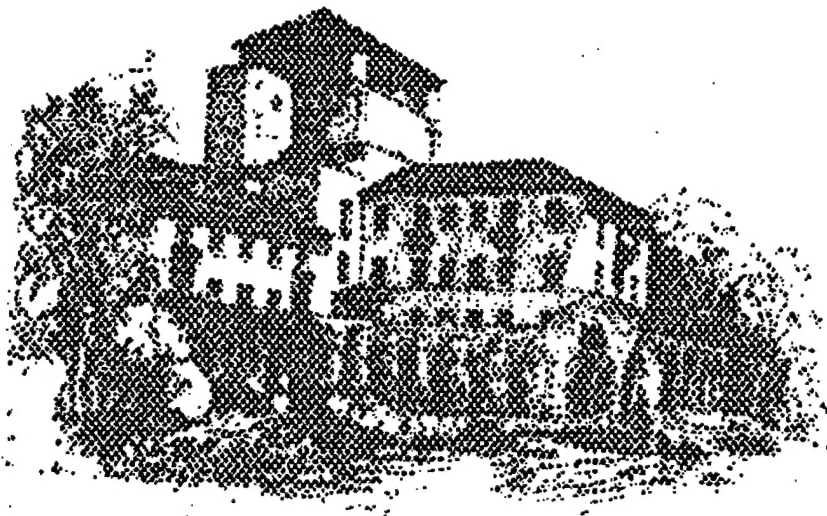
Introduction

Research is an integral part of graduate education. At the Naval Postgraduate School (NPS), the goals of research are to:

- Provide a meaningful, high quality, capstone learning experience for our students.

- Keep faculty on the leading edge of advances in defense-related science, technology, managment and policy to ensure that the latest information is incorporated into NPS courses and curricula.

- Apply faculty and student knowledge to enhance Navy/DoD operational effectiveness.

Pursuit of these goals increases the technical and managerial capability of the officer corps to keep pace with an increasingly complex defense posture in today's world.

The overall research program at NPS has two funded components:

- The Direct Funded Research (DFR) Program provides internal funding from the School's operating budget to stimulate innovative research ideas of benefit to the DoN and may be used for cost-sharing with reimbursable research efforts. This funding ensures, in particular, that all Navy-sponsored NPS curricula are equitably supported, that new faculty are provided an opportunity to establish a research program of importance to DoN/DoD and other national security interests, and that faculty and students from across the campus are encouraged to interact with one another.

- The Reimbursable Research (RR) Program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policy makers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. This ensures that NPS research remains highly regarded by academic peers and government officials and fosters a closer relationship between NPS and other outside organizations.

The two research programs are complementary and ensure that the overall research program is flexible, responsive, balanced and supportive of the unique needs of the military.

All research projects, both reimbursable and direct funded, support the School's research mission:

- To develop an overall research investment strategy that ensures a high quality, creative learning experience for NPS graduate students.

- To encourage faculty and student pursuit of new discoveries and applications which enhance the long term effectiveness of the armed forces.

- To stimulate interactions between NPS faculty and a wide variety of potential research sponsors (Government, Universities, Private Industry).

- To publicize (both internally and externally) significant achievements of the NPS research program and market NPS research capabilities.

- To foster synergy and force multiplication with Navy/DoD commands and laboratories to increase the potential for successful research and development programs

The Operations Research Department provides a carefully structured, graduate-level education in statistics and data analysis, probability, optimization, modeling and simulation, with emphasis on applications to military planning, doctrine, tactics, logistics, and procurement issues. The department has also developed and teaches graduate level courses in military operations research that cover such topics as search and detection, campaign analysis, combat modeling, test and evaluation, human factors in systems design, and cost and operational effectiveness analysis. Student thesis work is supervised by a faculty actively engaged in research on these topics, sponsored by various USN, USA, USAF, USMC, DOD, and NSF programs.

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OPERATIONS RESEARCH

Petho, Frank C.
CAPT (USN) & Chairman
OR/Pe
408-656-2381/2594 (phone)
408-656-2595 (fax)
fpetho@wposmtp.nps.navy.mil

Read, Robert R.
Professor & Associate Chair for Research
OR/Re
656-2382
rread@wposmtp.nps.navy.mil

Bailey, Michael
Associate Professor
OR/Ba
656-2085
mike@uwhiz.or.nps.navy.mil

Bloch, Paul S.
Lecturer
OR/Bc
656-3039
pbloch@wposmtp@nps.navy.mil

Bradley, Gordon H.
Professor
OR/Bz
656-2359
bradley@nextorserv.or.nps.navy
.mil

Brown, Gerald
Professor
OR/Bw
656-2140
gbrown@nps.navy.mil

Buss, Arnold
Visiting Assistant Professor
OR/Bu
656-3259
buss@nextkm.or.nps.navy.mil

Conner, George W.
Senior Lecturer
OR/Co
656-3306
gconner@wposmtp.nps.navy.mil

Dell, Robert F.
Assistant Professor
OR/De
656-2853
dell@sun10or.or.nps.navy.mil

Eagle, James N.
Professor
OR/Er
656-2654
jeagle@nps.navy.mil

Esary, James D.
Professor
OR/Ey
2780
jdesary@nps.navy.mil

Gaver, Donald P.
Distinguished Professor
OR/Gv
656-2605
dgaver@wposmtp.nps.navy.mil

Godat, Eric A., LCDR
Military Instructor
OR/Ge
656-3452
egodat@wposmtp.nps.navy.mil

Halwachs, T.E.
Lecturer
OR/Ha
656-2413
halwachs@nps.navy.mil

Hosford, John, LCDR (USN)
Military Instructor
OR/Hs
656-3113
jhohsford@wposmtp.nps.navy.
mil

Howard, Gilbert T.
Associate Professor
OR/Hk
656-3236

Hughes, Wayne P.
Senior Lecturer
OR/Hi
656-2484
whughes@wposmtp.nps.navy.mil

Jacobs, Patricia A.
Professor
OR/Jc
656-2258
pjacobs@wposmtp.nps.navy.mil

Kemple, William G.
Assistant Professor
OR/Ke
656-2191
kemple@nps.navy.mil

Kroshl, William M. CDR
Military Instructor
OR/Kb
656-2493
wmkroshl@nps.navy.mil

Larson, Harold J.
Professor
OR/La
656-2473
hlarson@wposmtp.navy.mil

Lawphongpanich, Siriphong
Associate Professor
OR/Lp
656-2106
slawphongpanich@wposmtp.
nps.navy.mil

Lewis, Peter A.W.
Professor
OR/Lw
656-2283
1526P@VM1.NPS.NAVY.MIL

Lind, Judith H.
Research Psychologist
OR/Li
656-2543
lind@scff.chinalake.navy.mil

Lindsay, Glenn F.
Associate Professor
OR/Ls
656-2688
glindsay@wposmtp.nps.navy.mil

Marshall, Kneale T.
Professor
OR/Mt
656-2474
kmarshall@wposmtp.nps.navy.
mil

Martin, Terryll R., LCDR (USN)
Military Instructor
OR/Tm
656-1016
tmartin@wposmtp.nps.navy.mil

Milch, Paul R.
Professor
OR/Mh
656-2882
pmilch@wposmtp.nps.navy.mil

Morton, David
Visiting Assistant Professor
OR/Mo
656-2302
dpmorton@nps.navy.mil

Nakagawa, Gordon R.
Lecturer
OR/Na
656-2303
gnakagawa@nps.navy.mil

Parry, Sam H.
Professsor
OR/Py
656-2779
sparry@wposmtp.nps.navy.mil

Prueitt, George C., LTC (USA)
Assistant Professor
OR/Pt
656-2636
gprueitt@wposmtp.nps.navy.mil

Purdue, Peter
Professor
OR/Pd
656-2381/2663
ppdrdue@wposmtp.nps.navy.mil

Redman, Terry, LCDR (USN)
Military Instructor
OR/Rt
656-3583
tredman@nposmtp.wps.navy.mil

Rosenthal, Richard E.
Professor
OR/Rl
656-2795
rosenthal@nps.navy.mil

Schrady, David
Professor
OR/So
656-2801
dschrady@nps.navy.mil

Shaw, Charles H., LTC (USA)
Military Instructor
OR/Sc
656-2636
cshaw@wposmtp.nps.navy.mil

Smyth, Gordon K.
Visiting Scholar
OR/Sg
656-2040
gsmyth@or.nps.navy.mil

Sohn, So Young
Assistant Professor
OR/Sh
656-3300
5258P@vm1.cc.nps.navy.mil

Sovereign, Michael G.
Professor
OR/Sm
656-2428
msovereign@nps.navy.mil

Taylor, James G.
Professor
OR/Tw
656-2683

Vassian, Robert B., CDR (USN)
Military Instructor
OR/Bb
656-2691
rvassian@wposmtp.nps.navy.mil

Washburn, Alan R.
Professor
OR/Ws
656-3127
awashburn@nps.navy.mil

Whitaker, Lyn R.
Associate Professor
OR/Wh
656-3482
whitaker@sun10or.or.nps.navy.
mil

Wood, Kevin R.
Associate Professor
OR/Wd
656-2523
kwod@wposmtp.nps.navy.mil

Woods, Walter M.
Professor
OR/Wo
656-2743
mwoods@wposmtp.nps.navy.mil

Youngren, Mark A., LTC (USA)
Military Instructor
OR/Ym
656-2281
myoungren@wposmtp.nps.navy
.mil

OPERATIONS RESEARCH

The research program in the Department of Operations Research seeks to advance the field's state of knowledge in areas important to the Department of Navy, Department of Defense, and military planning. The study of operational problems often involves the structuring and integration of a number of interdisciplinary components, and the result is a very rich collection of applications. In many instances, the methodologies developed are of general interest extending well beyond the problems that spawned them. In these cases our researchers will generalize their work and seek broader recognition.

This report contains the research summaries submitted by the department faculty for the calendar year 1995. For the convenience of the reader, a "summary of the summaries" appears in this cover statement. It is organized according to academic content, and the descriptions are largely in terms of the applied problems treated. Authors are identified in parentheses, and upon occasion, names of collaborators outside of our department are also identified. The specific areas currently represented are optimization, stochastic models and simulation, statistics and data analysis, combat modeling and war gaming. Sponsors are not immediately identified, but can be located in the individual summaries.

Tangible output appears in the form of student theses, reports to sponsors, conference presentations, Naval Postgraduate School technical reports, and refereed articles in the open professional literature. The research summaries of department faculty whose efforts involved projects sponsored outside of the department are reported by the department of the principal investigator. Also, research involving security or classified matters are not identified here.

Optimization

Research continues into the development of theory and algorithms for the solution of large-scale optimization models; The development of techniques for the automatic exploitation of special structure in linear programs and in branch-and-bound solutions of integer programs continues (Bradley, Brown, Wood). Portable C program modules are under development for graph and network algorithms.

Optimization models are under development for planning the acquisition and funding of theater missile defense systems (Brown, Dell). Work on the scheduling of Army base closure and realignment continues (Dell). A multi-period optimization model has been developed for on-time throughput of cargo (Rosenthal).

Linear programming models have been developed to place recruits in the Delayed Entry Program (Lawphongpanich). Work continues on algorithms for the realignment of Army recruiting stations (Lawphonpanich).

Stochastic Modeling and Simulation

The modeling of organic cell response to toxins continues (Gaver, Jacobs). Applied probability and statistical modeling of environmental problems was undertaken (Gaver, Jacobs). The International Ice Patrol drift model was extended to include iceberg track detection probabilities (Washburn).

The development of computerized forecasting methods to help anticipate the behavior of individual recruits participating in the Army's Delayed Entry Program continues (Milch, Whitaker). Other computerized management tools have been developed to facilitate the computation of loss rates at the battalion level (Milch).

The NPS Platform Foundation is being used to study scenarios relating to aircraft interoperability problems (Bailey, Brutzman). Work on the simulation of aspects of the Coast Guard's law enforcement methods continues (Bailey). The management of shop floor capacity, scheduling activities in stochastic networks, and the study of process flow in acquisition operations are projects under current treatment (Buss).

Statistics and Data Analysis

Models for managing recruiter production are being developed (Larson, Lawphongpanich). Research into the Army's recruiting resource planning system is under study (Larson, Read, Keller). An analysis of bonus payments is receiving special attention (Larson). Work continues on the generation and adaptation of algorithms for the Multi-String Rearranging Memory (Read).

Sampling plans are under development for the organized inspection of tanks and voids aboard aircraft carriers (Whitaker). Survival analysis is being applied to the TF34 aircraft engine data base in order to identify maintenance factors (Woods). Work on the quality assurance of major caliber ammunition continues (Bailey).

Human performance testing activities include the collection of infrared field data and the testing of night vision goggles (Krebs).

Wargaming and Combat Analysis

Work on tactical logistics support for battle forces continues (Schrady). Joint warfare topics are under study include: readiness assessment, sealift protection, and logistics command and control (Schrady).

Aspects of maneuver-at-sea doctrine have been developed (Hughes). Methods for evaluating tasks as performed by a joint staff are being developed (Parry). Two aspects of theater missile defense are under study (Marshall).

FY95 REIMBURSABLE PROGRAM
Department of Oceanography
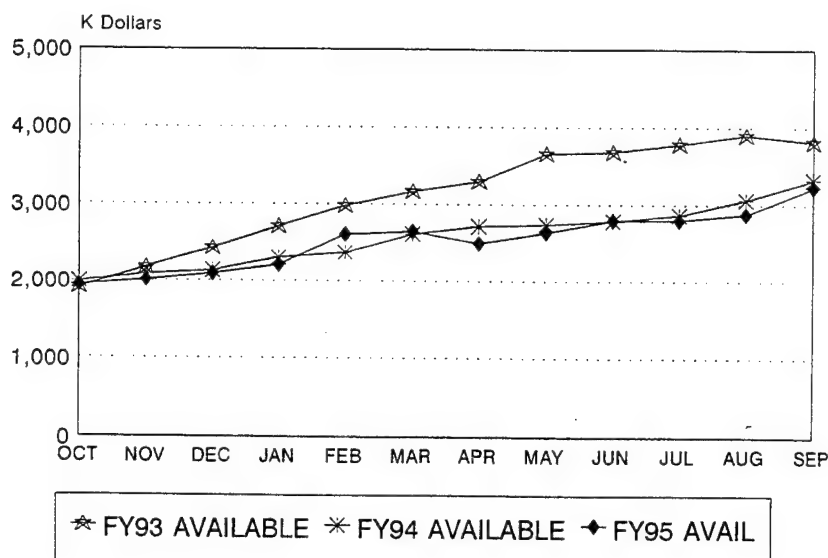
K Dollars

Figure 1. Reimbursable Funds Available by Fiscal Year.
This graph shows the amount of reimbursable funding available to the department. Dollar amounts include research and academic reimbursable activities.

DEFENSE 30%
ARMY 25%
NSF 2%
OTHER 5%
AIR FORCE 13%
NAVY 25%
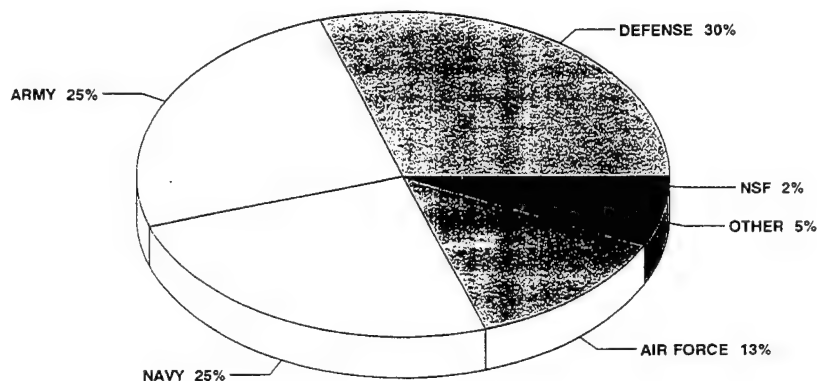
Figure 2. FY95 Reimbursable Sponsor Profile.

OPERATIONS RESEARCH

RELIABILITY AND QUALITY ASSURANCE OF MAJOR CALIBER AMMUNITION
Michael P. Bailey, Associate Professor
Department of Operations Research
Sponsor: Naval Surface Warfare Center - Crane Division

OBJECTIVE: To continue to refine the process for determining the required reliability of components of major caliber ammunition.

SUMMARY: This year the major improvements were to include logistical concerns into the process of modeling the effectiveness of a given ship-fill. The work was briefed at OPNAV-N81, to be included in the Naval Non-Nuclear Ordinance Requirement (NNOR) process.

DOD KEY TECHNOLOGY AREAS: Computing and Software, Other (Design Automation)

KEYWORDS: Simulation, reliability

INTERACTIVE SIMULATION AND OPTIMIZATION FOR SELECTING COAST GUARD LAW ENFORCEMENT ASSETS
Michael P. Bailey, Associate Professor
Robert Dell, Assistant Professor
Department of Operations Research
Sponsor: US Coast Guard Research and Development Center

OBJECTIVE: Two objectives were to conduct a validation study on LESIM, the USCG's topline law enforcement mission model, and to develop a methodology for integration of simulation and dynamic optimization processes.

SUMMARY: The two objectives were met. The LESIM model was tested in CY94 at the R&D Center, and at NPS. The report of the findings, including a growth path for the model into the coming years was delivered in CY95. In addition, the methodological work was continued this year.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Simulation

SIMULATION MODELING USING AN OBJECT CLASS TOOLBOX
Michael P. Bailey, Associate Professor
Department of Operations Research
Sponsor: US Army Logistics Management College

OBJECTIVE: To teach a shortcourse on the modeling techniques of object-oriented simulation modeling.

SUMMARY: A shortcourse of 35 hours of instruction was developed to teach the course. Professional-quality documentation of the course was developed and distributed to ALMC and the students, including lectures (Powerpoint), NPS tech reports, assignments, and software documentation. The students were also given a copy of the NPS Platform Foundation software.

OTHER:

Bailey, M. P., "NPS Platform Foundation," developed as an unfunded research project at NPS. (MODSIM Simulation Toolbox Programs)

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Simulation

AIR INTEROPERABILITY CENTER SIMULATION FOUNDATION
Michael P. Bailey, Associate Professor
Department of Operations Research
Donald Brutzman, Assistant Professor
Undersea Warfare Academic Group
Sponsor: Air Interoperability Center, Naval Air Station Pax River

OBJECTIVE: Provide an experiment prototyping facility for testing aircraft working together in a tactical environment.

SUMMARY: The Air Interoperability Center (AIC) is designed to address the inability of current Navy facilities to conduct RDT&E in the processes of communicating, managing, and fusing data in coordinated scenarios. We constructed a set of tools useful to the AIC for prototyping exercises for the aircraft so experiments can be designed and coordinated. The goal was to get a feel for what factors drive the outcomes before real aircraft testing begins. This year, we were able to achieve partial success by using the NPS Platform Foundation, along with implementation of DIS interfacing code to show capability. The work has not yet come to the point where software is deliverable, but the concept has been proven.

OTHER:

Brutzman, D.P., "NPS Platform Foundation DIS Interface," developed under this project. (C program)

DOD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Modeling and simulation

INCORPORATING PERSISTENCE IN LARGE-SCALE OPTIMIZATION MODELS
Gordon H. Bradley, Professor
Gerald G. Brown, Professor
R. Kevin Wood, Associate Professor
Department of Operations Research
Sponsor: Air Force Office of Scientific Research

OBJECTIVE: This continuing research program develops theory and algorithms for detecting and exploiting special structure in large-scale optimization models.

OPERATIONS RESEARCH

SUMMARY: Techniques were developed for automatic exploitation of special structure in linear programs and in branch-and-bound solutions of integer programming problems. The X-System linear/non-linear/integer optimizer was successfully married with the GAMS algebraic modeling system to make this state-of-the-art optimizer more widely available to users, especially in the DoD.

PUBLICATIONS:

Wood, K. and Washburn, A., "Two Person Zero-Sum Games for Network Interdiction," Operations Research, Vol. 43, pp. 243-251, 1995.

Brown, G., Arntzen, B., Harrison, T., and Trafton, L., "Global Supply Chain Management at Digital Equipment Corporation," INTERFACES, Vol. 25, pp.69-93, January-February 1995. (Nominated for the 1994 International Management Science Achievement Award) (35 minute videotape of 1994 International Management Science Achievement Award Competition, ORSA/TIMS Joint National Meeting, Boston, MA, April 24-27, 1994, College on the Practice of Management Science, Copyright 1994 and distributed by The Institute of Management Sciences, Providence, RI)

Brown, G., Bausch, D., and Ronen, D., "Consolidating and Dispatching Truck Shipments of Mobil Heavy Petroleum Products," INTERFACES, Vol. 25, pp. 1-17, March-April 1995.

CONFERENCE PRESENTATIONS:

Wood, K., "Solving a Generalized Generalized Assignment Problem," INFORMS, Los Angeles, CA, 23-25 April 1995.

Wood, K., "Optimal Target Selection for Striking Networks," ONR Workshop on Real-Time Strike Planning, George Mason University, Fairfax, VA, 18-19 July 1995.

Wood, K., "Military Applications of Optimization," Stanford University Operations Research Colloquium, Palo Alto, CA, 4 October 1995.

Bradley, G. and Drews, R., "Scheduling Basic Training for the Federal Armed Forces of Germany," INFORMS, New Orleans, LA, 29 October - 1 November 1995.

Brown, G., Bausch, D., and Ronen, D., "Consolidating and Dispatching Truck Shipments of Packaged Products," INFORMS, New Orleans, LA, 29 October - 1 November 1995.

Brown, G. and Olsen, M., "Exploiting Dynamic Factorization in Large-Scale Optimization," INFORMS, Los Angeles, CA, 23-25 April 1995.

THESES DIRECTED:

Drews, R., "Scheduling Basic Training for the Federal Armed Forces of Germany," Master's Thesis, March 1995.

Cormican, K., "Computational Methods for Deterministic and Stochastic Network Interdiction Problems," Master's Thesis, March 1995.

Leary, J., "Selecting a Stealthy Flight Path Through a Hostile Radar Defense Network," Master's Thesis, March 1995.

Aviles, S., "Scheduling Army Deployment to Two Nearly Simultaneous Major Regional Conflicts," Master's Thesis, September 1995.

Lee, S., "Route Optimization Model for Strike Aircraft," September 1995.

Wong, C., "Base Realignment and Closure Action Scheduler (BRACAS)," Master's Thesis, September 1995.

Druggan, P., "Optimal Allocation of Air Services to the U.S. Pacific Surface Forces," Master's Thesis, September 1995.

OTHER:

Wood, K., Cormican, K., and Morton, D., "Stochastic Network Interdiction," manuscript.

Wood, K. and Morton, D., "Solving a Stochastic Network Capacity Expansion Problem," manuscript.

Brown, G., Dell, R., and Farmer, R., "Scheduling Coast Guard District Cutters," INTERFACES, Vol. 26, to appear March-April 1996.

Brown, G., Cormican, K., Lawphongpanich, S., and Widdis, D., "Optimizing Submarine Berthing," manuscript.

DOD KEY TECHNOLOGY AREAS: Computing and Software, Other (Design Automation)

KEYWORDS: Large-scale optimization, scheduling

LARGE-SCALE OPTIMIZATION
Gordon H. Bradley, Professor
Gerald G. Brown, Professor
R. Kevin Wood, Associate Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: This continuing research program develops theory and algorithms for solution of large-scale optimization models.

SUMMARY: Techniques were developed for game theoretic modeling and methods to solve network interdiction problems for the optimal allocation of airborne assets to the interdiction of illegal drugs moving through air corridors of the Carribbean and Latin America. Separately, a system of portable C program modules has been developed to support the construction of efficient graph and network algorithms with capabilities to generate large-scale structured random graphs and networks and analyze test results.

PUBLICATIONS:

Wood, K. and Washburn, A., "Two Person Zero-Sum Games for Network Interdiction," Operations Research, Vol. 43, pp. 243-251, 1995.

Brown, G., Arntzen, B., Harrison, T., and Trafton, L., "Global Supply Chain Management at Digital Equipment Corporation," INTERFACES, Vol. 25, pp.69-93, January-February 1995. (Nominated for the 1994 International Management Science Achievement Award) (35 minute videotape of 1994 International Management Science Achievement Award Competition, ORSA/TIMS Joint National Meeting, Boston, MA, April 24-27, 1994, College on the Practice of Management Science, Copyright 1994 and distributed by The Institute of Management Sciences, Providence, RI)

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Brown, G., Dell, R., and Farmer, R., "Scheduling Coast Guard District Cutters," INTERFACES, Vol. 26, to appear March-April 1996.

Brown, G., Cormican, K., Lawphongpanich, S., and Widdis, D., "Optimizing Submarine Berthing," manuscript.

DOD KEY TECHNOLOGY AREAS: Computing and Software, Other (Design Automation)

KEYWORDS: Large-scale optimization, scheduling

OPERATIONS RESEARCH

PLANNING ACQUISITION OF THEATER MISSILE DEFENSE SYSTEMS
Gerald G. Brown, Professor
Robert F. Dell, Assistant Professor
Department of Operations Research
Sponsor: Office of the Under Secretary of Defense, Defense Systems (Acquisition and Technology)

OBJECTIVE: Develop optimization models to help select funding profiles for theater ballistic missile defense and cruise missile defense systems.

SUMMARY: The investigators are providing research, support, and development of optimization models tailored to resource allocation for acquisition of theater ballistic missile defense and cruise missile defense systems. The models will help identify the best method to provide desired systems given budget limitations through both years 2002 and 2010. Initial model design was completed in 1995.

DOD KEY TECHNOLOGY AREA: Other (Optimization)

KEYWORDS: Capital budgeting, optimization, mixed linear integer programming application

MODELING RESOURCE ALLOCATION IN WEAPON SYSTEMS ACQUISITION
Gerald G. Brown, Professor
Robert F. Dell, Assistant Professor
Department of Operations Research
Sponsor: Office of the Secretary of Defense (Program, Analysis and Evaluation)

OBJECTIVE: Develop optimization models to help select funding profiles for weapon systems.

SUMMARY: The investigators have provided consultation, research, support, and development of optimization models and supporting data for long-term capital budgeting referred to by the sponsor as: Resource Allocation in Weapon Systems Acquisition. The models identify optimal combinations of weapons systems which provide the greatest effectiveness given budget limitations over a future planning horizon. Initial model design and implementation of a proof prototype have been completed. The models have been refined for use with emergent issues in multi-service acquisition of alternate anti-armor weapon systems.

THESIS DIRECTED:

Ihde, A.G., "An Optimization Model for Anti-Armor Weapon Systems Acquisition," Master's Thesis, March 1995.

DOD KEY TECHNOLOGY AREA: Other (Optimization)

KEYWORDS: Capital budgeting, optimization, mixed linear integer programming application

CAPACITY PLANNING AND BOTTLENECK MANAGEMENT
Arnold H. Buss, Visiting Assistant Professor
Department of Operations Research
Sponsor: Unfunded

OBJECTIVE: This research studied optimal and heuristic capacity acquisition in stochastic production environments. Operational and economic impacts, and their interactions, were considered.

OPERATIONS RESEARCH

SUMMARY: The management of capacity and its interaction with shop-floor performance in realistic (i.e., stochastic) settings was studied with emphasis on financial/economic measures of performance. The economic bottleneck concept which was introduced, provided the ideal indicator for capacity acquisition. The research has moved to the study of the capacity decision in an international setting (a firm with plants in several countries). It was showed that for such a firm the use of excess capacity is more effective as a hedge against currency fluctuations than directly taking positions in the currency markets.

PUBLICATIONS:

Lawrence, S.R. and Buss, A.H., "Economic Analysis of Production Bottlenecks," Mathematical Problems in Engineering, Vol. 1, pp. 341-363, 1995.

Smunt, T., Buss, A.H., and Kropp, D.H., "Lot Splitting in Stochastic Job Shop and Flow Shop Environments," accepted for publication in Decision Sciences.

CONFERENCE PRESENTATION:

Buss, A.H. and Lawrence, S.R., "Locating the Economic Bottleneck," INFORMS National Meeting, New Orleans, LA, October 1995.

OTHER:

Lawrence, S.R. and Buss, A.H., "Locating the Economic Bottleneck," submitted to Decision Sciences. .

Buss, A.H. and Lawrence, S.R., "Excess and International Production Arbitrage," submitted for chapter in Advanced Manufacturing Systems: Strategic Management and Implementation.

DOD KEY TECHNOLOGY AREA: Other (Stochastic Production)

KEYWORDS: Monte Carlo Simulation, capacity analysis, bottlenecks

STOCHASTIC PROJECT MANAGEMENT
Arnold H. Buss, Visiting Assistant Professor
Department of Operations Research
Sponsor: Naval Postgraduate School

OBJECTIVE: This research develops optimal and heuristic methods for scheduling activities in projects in which the duration is random. The emphasis is on economic criteria, particularly expected net present value (ENPV).

SUMMARY: This was the only research of which the Principal Investigator was aware on optimal economic decisions for stochastic project networks. Careful consideration of the decisions under a project manager's control for random-duration projects involved defining the *delay* of an activity as the amount of time after its earliest start time an activity is initiated, given the realization of its predecessor activities' durations. Using ENPV criterion, the optimal delay in a Markov Project Network (MAN) was first determined. Then, to study the robustness of the solution, a simulation model was constructed to numerically solve non-Markov projects. The work is continuing with extensions of the method to incorporate penalties, deadlines, and other constraints.

OPERATIONS RESEARCH

PUBLICATIONS:

Buss, A.H. and Rosenblatt, M.J., "Activity Delay in Stochastic Project Networks," to appear in <u>Operations Research</u>.

Buss, A.H., "Sequential Experimentation for Estimating the Optimal Delay of Activities in PERT Networks," Proceedings of the 1995 Winter Simulation Conference, Crystal City, VA, December 1995.

Buss, A.H. and Rosenblatt, M.J., "Maximizing Expected Present Value in Projects with Stochastic Activity Durations: The Impact of Various Probability Distributions," technical report.

Buss, A.H. and Rosenblatt, M.J., "Crashing Activities in Stochastic Project Networks," technical report.

CONFERENCE PRESENTATIONS:

Buss, A.H. and Rosenblatt, M.J., "Time-Cost Tradeoffs in Stochastic Project Networks," INFORMS International Meeting, Singapore, June 1995.

Buss, A.H. and Rosenblatt, M.J., "Expanding and Compressing Activity Durations in Stochastic Project Networks," INFORMS National Meeting, New Orleans, LA, October 1995.

DOD KEY TECHNOLOGY AREA: Other (Networks)

KEYWORDS: Project management, Mauhou Processes, Monte Carlo Simulation

CYCLE TIME MEASUREMENT FOR IMPROVED ACQUISITION OPERATIONS
Arnold H. Buss, Visiting Assistant Professor
Department of Operations Research
Sponsor: Fleet and Industrial Supply Center - San Diego

OBJECTIVE: This work focuses on the process flow of contracts through FISC San Diego and contrasts the currently used Purchase Acquisition Lead Time (PALT) measure with that of Cycle Time (CT). Queueing and simulation models are being developed to analyze the impact of different process improvement measures on both PALT and CT. Currently effort is being focused on contracts less than $25,000. Subsequent work will extend the analysis to larger contracts, which have a different processing cycle.

SUMMARY: Although the data required to calibrate the models have not been put into useable form yet, initial runs indicated bottlenecks occurring at the buyers. Furthermore, inadequate technical reviews resulted in the contracts division having to redo that part of the process, resulting in waste. Consequently, plans were made to incorporate the technical review process into the contracts division. This will necessitate some changes in the model to reflect the new process. Currently, the final calibration of the models is awaiting the arrival of data from FISC in machine-readable form. Commander Phil Graham and his staff were briefed in January, 1996 on the status of the model.

DOD KEY TECHNOLOGY AREA: Other (Process Analysis)

KEYWORDS: Bottleneck, Cycle Time, throughput

OPERATIONS RESEARCH

SCHEDULING ARMY BASE REALIGNMENT AND CLOSURE ACTIONS
Robert F. Dell, Assistant Professor
Department of Operations Research
Sponsor: U.S. Army, Base Realignment and Closure Office

OBJECTIVE: Develop optimization models for scheduling base realignment and closure actions.

SUMMARY: This research produced an integer linear programming model, BRACAS (Base Realignment and Closure Action Scheduler). BRACAS optimally schedules base realignment and closure (BRAC) actions (*e.g.*, personnel realignments and construction schedules) in order to realize BRAC savings as soon as possible while satisfying yearly budget limits. During July and August 1995 the investigator used BRACAS to assist the Army develop implementation schedules and determine yearly budget levels for the Army's 1995 BRAC actions. The model was instrumental in showing an additional savings of $233 million over the required six-year planning horizon could be obtained by investing an additional $100 million in the 1997 budget.

THESIS DIRECTED:

Wong, C.G., "Base Realignment and Closure Action Scheduler (BRACAS)," Master's Thesis, September 1995.

OTHER:

Developed optimization model to schedule Army Base Realignment and Closure Actions.

DOD KEY TECHNOLOGY AREA: Other (Optimization)

KEYWORDS: BRAC, optimization, mixed linear integer programming application

APPLIED PROBABILITY AND STATISTICAL MODELING IN TOXICOLOGICAL AND ENVIRONMENTAL PROBLEMS
Donald P. Gaver, Distinguished Professor
Patricia A. Jacobs, Professor
Department of Operations Research
Sponsors: Naval Medical Research Institute, Toxicology Detachment
and Naval Postgraduate School

OBJECTIVE: To conduct mathematical research in applied probability modeling and evaluation of quantitative toxicology. The models usefully supplement, or even replace, certain large-scale time-consuming simulations. They have implications for joint operational situations.

SUMMARY: Properties of a stochastic greedy bin-packing algorithm were investigated. A statistical and economic assessment tool for the analysis of failure data has been developed to determine an optimal replacement time based on costs. Models of organic cell response to toxins have been proposed.

PUBLICATIONS:

Gaver, D.P., "Quantitative Modeling and Analysis in Environmental Studies," Chapter 9 in <u>Ecotoxicity and Human Health: a Biological Approach to Environmental Remediation</u>, F.J. de Serres and A.D. Bloom, eds., CRC Press, Inc., Boca Raton, FL, to appear in 1996.

Gaver, D.P. and Jacobs, P.A., "Asymptotic Properties of Stochastic Greedy Bin-packing," <u>Communications in Statistics-Stochastic Models</u>, Vol. 11, pp 333-348, 1995.

Gaver, D.P., Jacobs, P.A., and Dudenhoeffer, D.D., "Failure, Repair, and Replacement Analysis of a Navy Subsystem: Case Study of a Pump," Proceedings of the Seventh International Symposium on Applied Stochastic Models and Data Analysis, pp 201-210, 1995.

Gaver, D.P., Jacobs, P.A., and Carpenter, R.L., "Note on an Alternative Mechanism for Logistic Growth," Naval Postgraduate School Technical Report, NPS-OR-95-013, November 1995.

Gaver, D.P., Jacobs, P.A., Carpenter, R.L., and Burkhart, J.G., "A Mathematical Model for Intra-cellular Effects of Toxins on DNA Adduction and Repair," Naval Postgraduate School Technical Report, NPS-OR-95-012, November 1995.

CONFERENCE PRESENTATIONS:

Gaver, D.P., Jacobs, P.A., and Dudenhoeffer, D.D., "Failure, Repair, and Replacement Analysis of a Navy Subsystem: Case Study of a Pump," Seventh International Symposium on Applied Stochastic Models and Data Analysis, Dublin, Ireland, 12-15 June 1995.

Gaver, D.P., Jacobs, P.A., and Carpenter, R.L., "Chemical Effects on Cells as Problems in Population Dynamics," Fourth International Conference on Mathematical Population Dynamics, Houston, TX, 23-27 May 1995.

THESES DIRECTED:

Michal, J.J., "Reliability Modeling and Estimation Using U.S. Navy 3M Maintenance Data," Master's Thesis, September 1995.

Paulsen, N.C., "A Waste Management Plan for U.S. Ships," Master's Thesis, September 1995.

Race, L., "A Stochastic Approach to the Pharmacotherapeutic Management of Chronic Moderate Adult Asthma," Master's Thesis, September 1995.

OTHER:

Gaver, D.P., Jacobs, P.A., and Carpenter, R.L., "Stochastic Models for Cell Signaling and Toxic Effects on Cells," forthcoming.

DOD KEY TECHNOLOGY AREAS: Human Systems Interface, Environmental Quality

KEYWORDS: Stochastic models, dose-response models, biological cells, toxic chemicals, bioassay, bin packing, reliability and maintainability

OPERATIONS RESEARCH

QUANTITATIVE TOXICOLOGY
Donald P. Gaver, Distinguished Professor
Patricia A. Jacobs, Professor
Department of Operations Research
Sponsor: U.S. Army Biomedical Research and Development Laboratory

OBJECTIVE: To initiate an effort to provide quantitative, data-based assessments of toxicological phenomena relevant to Army goals and to advance the quantitative methodology needed for the assessments.

SUMMARY: Statistical analyses of data from histopathologic examination of Japanese Medaka from health screens have been performed. The analyses indicate unexplained variation between the health screens. This unexplained variability may indicate compromised health in the fish. An analysis of data from a pathology report for an interim sacrifice for a field experiment using Japanese Medaka has also been performed. The analysis indicates statistically significant associations between endpoints and experimental variables.

PUBLICATIONS:

Gaver, D.P., Jacobs, P.A., and Carpenter, R.L., "Note on an Alternative Mechanism for Logistic Growth," Naval Postgraduate School Technical Report, NPS-OR-95-013, November 1995.

Gaver, D.P., Jacobs, P.A., Carpenter, R.L., and Burkhart, J.G., "A Mathematical Model for Intra-cellular Effects of Toxins on DNA Adduction and Repair," Naval Postgraduate School Technical Report, NPS-OR-95-012, November 1995.

OTHER:

Gaver, D.P. and Jacobs, P.A. attended an interagency workshop on biological models for assessing environmental toxicity in Columbia MO, 19-20 April 1995.

Gaver, D.P. and Jacobs, P.A., "Proposal for Research in Quantitative Bioassay Methodology and Risk Analysis and Characterization," Annual Report 11 January 1994 - 11 January 1995, 1995.

Gaver, D.P. and Jacobs, P.A., "Proposal for Research in Quantitative Bioassay Methodology and Risk Analysis and Characterization," Final Report 11 January 19993 - 30 December 1995, forthcoming.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Combining information, data analysis of bioassay data, generalized linear regression, analysis of variance, missing data

OPERATIONS RESEARCH

ANALYTICAL TOOL DEVELOPMENT FOR JOINT THEATER-LEVEL
MODELS OF THE FUTURE
Donald P. Gaver, Distinguished Professor
Sam H. Parry, Professor
Patricia A. Jacobs, Professor
Mark A. Youngren, LTC (USA), Assistant Professor
Department of Operations Research
Sponsors: Conventional Forces Analysis Division, J-8, The Joint Staff
and Naval Postgraduate School

OBJECTIVE: Purpose of the research is to extend and enhance capabilities of the Joint theater level model architecture developed at NPS. The emphasis is on modeling the impact of information obtained from realistically imperfect sensor systems, data fusion and combat on interactive and joint conflicts.

SUMMARY: New models for sensors and the allocation of sensor effort have been formulated. The effect of various levels of sensor effort on combat has been and is being modeled in various scenarios. Representations of combat processes operating under uncertainty have been developed, primarily in student theses. A software prototype has been developed to test and demonstrate research results.

PUBLICATIONS:

Almeida, R., Gaver, D.P., and Jacobs, P.A., "Simple Probability Models for Assessing the Value of Information in Defense Against Missile Attack," Naval Research Logistics, Vol.42, pp. 535-547, 1995.

Gaver, D.P., Jacobs, P.A., and Youngren, M.A., "Asymptotic Properties of a Sensor Allocation Model," Naval Postgraduate School Technical Report, NPS-OR-95-002, May 1995.

CONFERENCE PRESENTATIONS:

Gaver, D.P., Jacobs, P.A., Parry, S.H., and Youngren, M.A., "Intelligence and Fusion in the Future Theater Level Model," INFORMS National meeting, Los Angeles, CA, 23-26 April 1995.

Gaver, D.P., Youngren, M.A., Jacobs, P.A., and Parry, S.H., "Future Theater Level Model Overview," INFORMS National Meeting, Los Angeles, CA, 23-26 April 1995.

Gaver, D.P. and Jacobs, P.A., "Attrition Modeling with Decoys: an OOTW Motivation," INFORMS National Meeting, New Orleans, LA, 29 October - 29 November 1995. (Paper submitted to a journal)

Youngren, M.A., "Modeling Third Wave Joint Military Operations," INFORMS National Meeting, Los Angeles, CA, 23-26 April 1995.

Gaver, D.P., Jacobs, P.A., Parry, S.H., and Youngren, M.A., "The Models of J-STOCHWARS," Operations Research Department Seminar, 19 July 1995.

Gaver, D.P., Jacobs, P.A., and Youngren, M.A., "J-STOCHWARS," Presentation to Information Warfare Working Group, January 1995.

Gaver, D.P. and Jacobs, P.A., "Purposeful Sensors," Technical Trade & Cooperation Program (TTCP) Working Group 6 Meeting, Toronto, Canada, May 1995.

Youngren, M.A., "Capturing Uncertainty in Theater-Level Modeling," NATO Panel 7 Symposium on Uncertainty in Defense Decision Making, The Hague, Netherlands, January 1995. (Published in proceedings)

Youngren, M.A., Gaver, D.P., Jacobs, P.A., and Parry, S.H., "Joint STOCHWAR," Technical Trade & Cooperation Program (TTCP) Working Group 6 Meeting, Toronto, Canada, May 1995.

Youngren, M.A., Gaver, D.P., and Jacobs, P.A., "Modeling Joint Theater-Level C3I," Military Operations Research Society Symposium (MORSS), U.S. Naval Academy, Annapolis, MD, June 1995.

Youngren, M.A., Gaver, D.P., and Jacobs, P.A., "Modeling the Impact of Joint Theater-Level Intelligence," Military Operations Research Society Symposium (MORSS), U.S. Naval Academy, June 1995.

THESES DIRECTED:

Lim, C.K., "Modeling of Special Force Operations for Strategic Objectives in the Joint Warfare Analysis Experimental Prototype," Master's Thesis, September 1995.

Hamman, J., "Theater Air Apportionment and Allocation: Application of Dynamic Algorithms for Combat Models," Master's Thesis, September 1995.

Wilk, T., "Theater Level Operations: Modeling Ground Unit Logistical Requirements in the Joint Warfare Analysis Experimental Prototype," Master's Thesis, September 1995.

Whitlock, J., "Modeling Obstacles and Engineer Forces in Stochastic Joint Theater Models," Master's Thesis, September 1995.

Slavik, N., "Development of a Forced Entry Mission Objective Selection Algorithm for Implementation into the Joint Warfare Analysis Experimental Prototype," Master's Thesis, December 1995.

Bowyer, R., "Modeling Corps Artillery in a Theater-Level Model," Air Force Institute of Technology (AFIT) Master's Thesis, March 1995.

Oliver, J.M., "A Model for Estimating the Collateral Damage Resulting from Intercepted Theater/Tactical Ballistic Missile," Master's Thesis, March 1995.

Monteith, B.G., "An Analysis of the Impact of Sensor Cueing and Cooperative Engagement in the Theater Ballistic Missile Defense (U)," Master's Thesis, September 1995.

OTHER:

Yamauchi, H., Joint Warfare Analysis Experimental Prototype, version 2.0, Simscript software, December 1995.

Gaver, D.P., Jacobs, P.A., and Youngren, M.A., "Binomial-like Sensors," in progress.

Gaver, D.P., Jacobs, P.A., Youngren, M.A., and Parry, S.H., "Models for force interaction that involve uncertain perception," forthcoming.

Youngren, M.A. and Lovell, N., Joint Warfare Analysis Experimental Prototype Users' Manual (version 2.0), in progress.

DOD KEY TECHNOLOGY AREAS: Human Systems Interface, Modeling and Simulation

KEYWORDS: Combat models, Bayesian perception updating, decision analysis, C3I, command and control, intelligence, joint theater models

OPERATIONS RESEARCH

THE DOCTRINE OF MANEUVER WARFARE AT SEA
Wayne P. Hughes, Jr., Senior Lecturer
Department of Operations Research
Sponsor: Naval Doctrine Command

OBJECTIVE: This two year project is in support of the development by the Naval Doctrine Command of current doctrine for maneuver warfare at sea during FY 95-96. Support is in the form of working papers on maneuver warfare at the strategic, operational and fleet tactical levels with emphasis on joint and combined operations in the contemporary environment. The principal investigator is also available for personal consultation to review doctrine in draft.

SUMMARY: The principal investigator has prepared and presented an outline of the salient aspects of a robust doctrine to assist the sponsor in writing fundamental publications (the NDP series). He has made recommendations to improve *NDP-3, Operations*. He attended two meetings as a member of the Doctrine Command's Academic Advisory Group to assist in preparation and dissemination of doctrine. He published a short comment in the Naval Institute *Proceedings* on an article by MGEN Atkeson in that journal. Work remaining to fulfill the contract is a publishable article based on the outline presented to the Doctrine Command.

PUBLICATIONS:

Hughes, W.P., Jr., "The Power In Doctrine," Naval War College Review, Summer 1995.

Hughes, W.P., Jr. Comment on E. B. Atkeson, "Maneuvering Past Maneuver Warfare," accepted for publication in the March 1996 issue of the Naval Institute.

CONFERENCE PRESENTATION:

Hughes, W.P., Jr. "Naval Maneuver Warfare," Meeting of the Naval Doctrine Command Academic Advisory Group, November 1995.

DOD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation

KEYWORDS: Doctrine, maneuver warfare, naval operations, naval tactics

CHAIR OF APPLIED SYSTEMS ANALYSIS
Wayne P. Hughes, Jr., Senior Lecturer
Department of Operations Research
Sponsor: Office of the Chief of Naval Operations (N-81)

OBJECTIVE: To support activities designated in the MOU between the Superintendent, NPS, and the Director, Assessment Division, CNO (N-81)

SUMMARY: Support consisted of two visits to the sponsor's office to facilitate the initiation of faculty research, sponsorship of student experience tours to the sponsor's office and other tours consistent with the sponsor's objectives, encouragement of related thesis work, and advising on seven theses, most of which will be completed in 1996. The principal investigator responded to queries about Campaign Analysis in support of the sponsor's new work in that form of modeling and analysis. He attended the first Naval Operations Research Conference (NORC I). With N-81 encouragement, he devoted many hours to a third addition to *Military Modeling*, a 325 page monograph published by the Military Operations Research Society of which N-81 is a sponsor. He also contributed to the sponsor's objectives by serving as a primary reviewer of the third edition of the book, *Naval Operations Analysis*, in preparation for

publication in 1996.

PUBLICATION:

Hughes, W.P., Jr., editor, <u>Military Modeling for Decision Making</u>, Alexandria, VA, MORS, forthcoming 1996.

THESES DIRECTED:

Kuepper, A.R., "Analysis of Current and Projected Force Structures on PACFLT ASW Effectiveness in a Single Major Regional Contingency (U)," SECRET NOFORN, Master's Thesis, March 1995.

Polidoro, M., "The Use of Patrol Craft in Low Intensity Conflict Operations," Master's Thesis, December 1995.

DOD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Naval operations analysis, systems analysis, patrol craft

DEVELOPMENT OF SPECIAL OPERATIONS/LOW INTENSITY CONFLICT (SO/LIC) CAMPAIGN ANALYSIS COURSE AND SUPPORT OF OTHER JOINT WARFARE ANALYSIS COURSES
Wayne P. Hughes, Jr., Senior Lecturer
Department of Operations Research
Sponsor: Naval Postgraduate School - Institute for Joint Warfare Analysis

OBJECTIVE: To create a course for Special Operations students that is a derivative of OA4602 Joint Campaign Analysis. A secondary objective is to assist in the development of the Joint Warfare Analysis (JWA) curricula, including research in combat theory.

SUMMARY: A trial approach to teaching 21 Special Operations students will be conducted during the spring quarter of 1996. Only a small amount of time has been devoted to JWA curriculum planning and development. Instead, the principal investigator has been appointed Director of a new Special Warfare Center under the Institute for JWA, a new initiative of the Superintendent and Provost which was unfunded in 1995, and as a member of the Weir Committee assisted in realignment of the SO/LIC academic program to better meet the sponsor's needs.

THESES DIRECTED:

Cobb, C.B.R., "Combating Maritime Piracy," Master's Thesis, December 1994.

Frietas, M. and Treadway, B., "Fluvial Myth: Past and Present U. S. Riverine Operations," Master's Thesis, December 1994.

DOD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Special warfare, special operations, operations other than war, low intensity conflict

OPERATIONS RESEARCH

NIGHT VISION GOGGLE HUMAN PERFORMANCE TESTING AND DATA COLLECTION STUDY (1)

William K. Krebs, Assistant Professor
Aviation Safety Programs and Department of Operations Research
Sponsor: Naval Aerospace Medical Research Laboratory

OBJECTIVE: This research will develop a small group of visual performance tests that will comprehensively measure visual perception and thus provide a metric for comparing alternative visual digital enhancement techniques.

SUMMARY: **Study 1.** A variation of the standard visual search paradigm was used to test the impact of various single band and dual band image types in improving preattentive perception of natural scenes. Independent variables were Sensor (I^2, IR, fused I^2 and IR non color, and fused I^2 and IR color), Scene Condition (illumination was 1.00E-03 to 1.00E-02 lux), and Location (target presented in three different locations). The subject's task was to determine whether an 8.6^0 target (e.g. truck) was embedded within the background consisting of the natural image (e.g. a field with a forest in the background). Reaction time was measured on a single-interval present/absent task. **Results.** Subjects reaction time for target present (742ms) and target absent (893ms) showed a significant difference of 150ms. Subjects showed no significant difference between sensors (fused color (816ms), fused non-color (819ms), IR (793ms), and I^2 (838ms)). **Conclusions.** Reaction time for target absent scenes are indicative of an extended, self-terminating search. The lack of a difference between sensors may be due to scene composition favoring or hindering target detection capabilities equally across sensors. Therefore scenes composed of contrasting capabilities are being tested.

Study 2. Registered IR, ll and color (false-color images derived from IR and ll images) images of real-world scenes were used on a target-detection task. 1.5° patches were cut from the images to serve as "target" or "distractors". Target patches contained a designated class of object (e.g., buildings). To avoid artifacts inherent in using real images (luminance, contrast, or texture cues): 1) image patches were selected of approximately equal luminance and "jittered" stimulus values (e.g., luminance) by mixing patches with different examples of the target and different distractors across trials, and 2) results were examined across a variety of objects and scenes to get an over-all measure of functional enhancement. A single-interval yes/no paradigm was used to measure d' for the 100 msec flashed (and masked) images. **Results.** Although performance for idiosyncratic targets is better on ll or even IR images, in general fused-color images provide vastly superior real-world object detection performance (d' of approximately 3.0 vs .5 on this task). **Conclusion.** It has been documented that certain night-vision enhancement methods are superior to others as measured functionally in terms of human perceptual performance.

OTHER:

Essock, E.A., McCarley, J.S., Sinai, M.J., and Krebs, W.K., "Functional Assessment of Night-vision Enhancement of Real-world Scenes," submitted to Investigative Ophthalmology and Visual Science.

Sampson, M.T., Krebs, W.K., Scribner, D.A., and Essock, E.A., " Visual Search in Natural (visible, infrared, and fused visible and infrared) Stimuli," submitted to Investigative Ophthalmology and Visual Science.

Krebs, W.K., Lobik, D., Therrien C., and Essock, E.A., "Is an Integrated dog(s) or Wavelet Transform the Best Method to Model Sensitivity Profiles Underlying Desensitization-sensitization Data," submitted to Investigative Ophthalmology and Visual Science.

DOD KEY TECHNOLOGY AREAS: Human Systems Interface, Sensors, Other (Electro Optical Displays)

KEYWORDS: Sensor fusion, multi-spectral displays, visual psychophysics, human performance

OPERATIONS RESEARCH

NIGHT VISION GOGGLE HUMAN PERFORMANCE TESTING
AND DATA COLLECTION STUDY (2)

William K. Krebs, Assistant Professor
Aviation Safety Programs and Department of Operations Research
Sponsor: Office of Assistant Secretary of Navy

OBJECTIVE: The Applied Optics Division, Naval Research Laboratory, collected visible and infrared (IR) field data at Kittyhawk, NC, August 1995. This data enabled the experimenter to view the differences between visible, Mid-Wave IR, and an image intensifier tube while viewing various targets embedded in different types of terrain.

SUMMARY: This databse of images illustrated that complementary information from different spectral sensors enhanced target detection during different illumination and atmospheric conditions. Furthermore, simulations of the LLCCD demonstrated that a one electron readout noise image was significantly better in visual search performance compared to four electron readout noise image. This finding will provide valuable requirement input into the "Color Night Vision System" which is currently being sponsored by N88. Images were not matched for field of view so visual psychophysical tests could not be conducted, however visual inspection of the images illustrated that the infrared images provided significantly more information compared to the other sensors. The results of this data collection has led to further interest in multi-spectral displays and fusing multiple spectral bands into a single sensor. Further studies in FY96 will be conducted sponsored by OASN and Naval Medical Research and Development Command while flying a fused sensor on an aviation platform.

OTHER:

The Naval Research Laboratory, Applied Optics Division, and the Naval Postgraduate School will demonstrate and test a color sensor fusion system using the Nite Hawk pod on a F/A-18 aircraft in FY96. This system will quantify the degree to which a FLIR/LL color fusion system will improve situational awareness and standoff range for Navy and Marine Corps pilots operating high performance aircraft.

The hardware configuration will be a Loral Nite Hawk pod with a Gen III intensified CCD camera mounted behind the laser entrance window. The Nite Hawk pod is currently operates with a Gen I FLIR. The reconfigured pod will be mounted on the NASA's F/A-18 aircraft specially configured to accept electro-optical test systems. The intensified sensor output is in a standard video format and will be recorded on a high quality VCR recorder. Post flight data analysis will be performed at both Naval Research Laboratory and Naval Postgraduate School.

DOD KEY TECHNOLOGY AREAS: Human Systems Interface, Sensors, Other (Electro-Optical Displays, Infrared Displays)

KEYWORDS: Sensor fusion, multi-spectral displays, visual psychophysics, human performance, infrared displays, low light sensors

OPERATIONS RESEARCH

ELECTRONIC ENHANCEMENT OF NIGHT VISION GOGGLES IMAGERY AND VISIBLE/LONG WAVE INFRARED FUSION

William K. Krebs, Assistant Professor
Aviation Safety Programs and Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: To increase the utility of night vision goggles (NVGs) and forward looking infrared (FLIR) devices for the military user.

SUMMARY: An Advanced Technology Demonstration (ATD) "Color Night Vision System - Pit Viper" was submitted (Nov 94) and it placed second in the FY97 start projects. This project is scheduled to receive $12.35M between FY97 to FY99 with N88 identifying a 6.4 transition for FY00 and beyond. Furthermore, a wide range of support has been obtained from N88, N85, N093, N09F, N86, and N87 to transition this device to each community. In addition, the Assistant Secretary of the Navy Forces and Resources (OASD(SO/LIC)) supports the project because the resulting product will fulfill specific SPECWAR needs.

Visual Segmentation Tasks: A locally adaptive contrast enhancement technique has shown significant improvement compared to original images, edge enhanced images, as well as other visual neurophysiology algorithms proposed by other researchers.

Different Input Sensors: Field data collected from a variety of sensors, such as LLCCDs, LLTVs, Gen III tubes, MWIR and LWIR, indicates that a dual band sensor comprised of two infrared bands may in fact be better than a visible and infrared band for detection and classification of targets. These results will be further investigated in FY96 an improved experimental design that will test combinations of equipment by illumination by terrain by target by algorithm enhancement. And, these preliminary results could impact the direction of the ATD as to whether a LLCCD or two IR bands will be used.

PUBLICATION:

Prather, J.R., Krebs, W.K., Sinai, M.J., McCarley, J.S., and Essock, E.A., " Oblique Orientations are Confused in Visual Search," Investigative Ophthalmology and Visual Science, SUPPL(36), 4132, 1995.

CONFERENCE PRESENTATION:

Krebs, W.K., "Color Night Vision System - Pit Viper," Science and Technology Working Group, Naval Surface Warfare Center, Carderock, MD, 28 June 1995.

OTHER:

The project will continue in FY96. The goals for FY96 will be: 1) visual psychophysical tests on sensor fusion data, 2) evaluation of sensor fusion algorithms (speed, compatibility, requirements), and 3) human fact issues of color night vision at night.

DOD KEY TECHNOLOGY AREAS: Human Systems Interface, Sensors, Other (Electro Optical Displays)

KEYWORDS: Sensor fusion, multi-spectral displays, visual psychophysics, human performance

OPERATIONS RESEARCH

ANALYSIS OF RECRUITING RESOURCE PLANNING SYSTEMS

Harold J. Larson, Professor
Robert R. Read, Professor
Department of Operations Research
C.M. Keller, Assistant Professor
Defense Resource Management Institute
Sponsor: U.S. Army Recruiting Command

OBJECTIVE: The currently employed elasticities for enlistment bonuses and education benefits are possibly inaccurate, relative to other terms in the models. The data and model used to estimate these elasticities will be reviewed and the use of more recent data and other techniques will be explored.

SUMMARY: The United States military recruiting commands are tasked with providing new recruits in sufficient numbers, of the correct types, to maintain the national defense. To accomplish this they are authorized by Congress to advertise and to offer certain incentives to attract eligible persons into the required billets. These programs involve costs and, with increasingly severe budget restrictions, it is important that the dollars available be spent in the best possible manner. A number of fairly recent studies have attempted to estimate the relative effects of advertising and various other incentives on the production of enlisted contracts. This paper discusses some issues involved in such estimation, reviews the data used in one recent study, and employs this data to estimate several alternative models of contract production. Recommendations are made about collecting and maintaining accurate data for the investigation of tradeoffs of resource allocations.

CONFERENCE PRESENTATION:

Daula, T., Keller, C.M., Larson, H.J., and Read, R.R., "Support for the Recruiting Cost Component of the Resource Planning System," Joint Market Analysis and Research Committee; Annual Symposium, San Antonio, TX, 28-30 March 1995.

OTHER:

Draft report has been prepared for review. Technical report will be issued in Spring, 1996. Thesis, Wargelin, M., to be completed.

DOD KEY TECHNOLOGY AREA: Other (Cost Benefit Analysis)

KEYWORDS: Econometrics, elasticity, multi-equation regression

MODELS FOR MANAGING RECRUITER PRODUCTION

Harold Larson, Professor
Sirphong Lawphongpanich, Associate Professor
Department of Operations Research
Sponsor: Navy Recruiting Command

OBJECTIVE: Using the most recent data possible, Poisson regression will be used to estimate contract production by recruiting station and by individual recruiters, taking account of various economic and demographic variables.

SUMMARY: This project will produce models for station and individual recruiter productivity, using the most recently available data. Programs have been designed to carry out Poisson regression modelling, using demographic and economic data linked to contract production. Some preliminary data has been received and analysed; more complete

data sets are expected which will allow exploration of more accurate and realistic models. This project will be completed after receipt of the richer data set.

PUBLICATION:

Larson, H.J., "Analysis of Recruiting Bonus Payments," Naval Postgraduate School Technical Report, NPS-OR-95-001, February 1995.

CONFERENCE PRESENTATION:

Larson, H., "Analysis of Recruiting Bonus Payments", INFORMS Los Angeles Spring meeting, Los Angeles, CA, 26 April 1995.

OTHER:

A technical report will be issued on completion of this project.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Statistical forecasting, regression, military recruiting

OPTIMAL DELAY ENTRY PROGRAM PLACEMENT POLICY
Siriphong Lawphongpanich, Associate Professor
Department of Operations Research
Sponsor: Navy Recruiting Command

OBJECTIVE: To develop a decision aid tool that is useful in managing the Delay Entry Program (DEP) at the Navy Recruiting Command.

SUMMARY: This projected started in November 1995. During the time period between November and December of 1995, two different linear programming models were developed to optimally place recruits into the Delay Entry Program at different lengths. One model minimizes the expected cost which includes the cost due to DEP loss and attrition during the first term of enlistment. The other maximizes the minimum probability of attaining the monthly recruiting goals.

DOD KEY TECHNOLOGY AREA: Manpower, Personnel and Training

KEYWORDS: Linear programming, manpower planning, attrition and recruiting

OPERATIONS RESEARCH

REALIGNMENT OF ARMY RECRUITING STATIONS
Siriphong Lawphongpanich, Associate Professor
Department of Operations Research
Sponsor: U.S. Army Recruiting Command

OBJECTIVE: To develop optimization models to support the ongoing realignment of Army recruiting stations.

SUMMARY: During this reporting period, we concentrated on developing a heuristic algorithm for the mathematical programming models developed earlier. Preliminary results indicated that the heuristic algorithm generates good solutions for the models. The algorithm was implemented in FORTRAN and empirically tested using the data from 1994.

CONFERENCE PRESENTATION:

Lawphongpanich, S., "Optimization Models for Realignment of Recruiting Territories," INFORM Conference, Los Angeles, CA, April 1995.

DOD KEY TECHNOLOGY AREA: Manpower, Personnel and Training

KEYWORDS: Optimization, regression, and recruiting

OPTIMAL REALIGNMENT OF U.S. ARMY RECRUITING STATIONS
Siriphong Lawphongpanich, Associate Professor
Department of Operations Research
Sponsor: U.S. Army Recruiting Command

OBJECTIVE: To develop optimization models to support the ongoing realignment of Army recruiting stations.

SUMMARY: During this reporting period, we concentrated on developing a heuristic algorithm for the mathematical programming models developed earlier. Preliminary results indicated that the heuristic algorithm generates good solutions for the models. The algorithm was implemented in FORTRAN and empirically tested using the data from 1994.

CONFERENCE PRESENTATION:

Lawphongpanich, S., "Optimization Models for Realignment of Recruiting Territories," INFORM Conference, Los Angeles, CA, April 1995.

DOD KEY TECHNOLOGY AREA: Manpower, Personnel and Training

KEYWORDS: Optimization, regression, and recruiting

OPERATIONS RESEARCH

BALLISTIC MISSILE DEFENSE OFFICE RESEARCH SUPPORT FOR 1995
Kneale T. Marshall, Professor
Department of Operations Research
Sponsor: Ballistic Missile Defense Office

OBJECTIVE: This research is in support of the Theater Missile Defense (TMD) Group within BMDO. It is based on the adaptation of Anti-Submarine Warfare (ASW) philosophy, tactics and systems, to land-based search and detection.

SUMMARY: Funding for this project started in September 1993. Two quarters were devoted to this project in FY95. Principal activities in the Operations Research Department included publication of a paper on quantifying counterforce and active defense in countering theater ballistic missiles (TBM's). It has been shown that effective counterforce will be a necessary part of TMD. Effort in FY95 was concentrated on how to achieve effective counterforce. Progress has been made on modeling searching along roads. An MS thesis was completed in this area (Junker) that included the role of unmanned air vehicles. Principal activities in the National Security Affairs Department included showing how the philosophy that influenced ASW operations can be used to guide counterforce attacks against mobile missiles. Currently two technical reports are in progress, one on sensor and search platform performance, and one on the suppression effects of searching for TELs.

PUBLICATIONS:

Marshall, K.T., "Quantifying Counterforce and Active Defense in Countering Theater Ballistic Missiles," Military Operations Research, Vol. 1, pp. 35-48, 1995.

Wirtz, J., "Allies and Theater Missile Defense: an ASW Approach to the Scud Hunt," Defense Analysis, Vol. 11, 1995.

Wirtz, J., "Counterforce and Theater Missile Defense," Strategic Studies Institute, U.S. Army War College, Carlisle Barracks, PA, 1995.

THESIS DIRECTED:

Junker, V.L., LT, USN, "Tactical Unmanned Aerial Vehicles in a Proposed Joint Infrastructure to Counter Theater Ballistic Missiles," Master's Thesis, March 1995.

DOD KEY TECHNOLOGY AREAS: Sensors, Command, Control and Communications (C3)

KEYWORDS: Theater Missile Defense, sensors, tactics, C3, international cooperation

INSTITUTE FOR JOINT WARFARE ANALYSIS RESEARCH SUPPORT FOR 1995
Kneale T. Marshall, Professor
Department of Operations Research
Sponsor: Naval Postgraduate School - Institute of Joint Warfare Analysis

OBJECTIVE: This research is to model the effects of attack operations in Theater Missile Defense (TMD) on suppression of launcher operations as a measure of effectiveness in countering Theater Ballistic Missiles.

SUMMARY: Funding for this project amounted to one academic quarter for the period October - December, 1995. It has been shown that effective attack operations will be a necessary part of TMD. Historically, efforts in this area have not proved successful in terms of hard kills of launchers, but there is some evidence that the presence of searchers and attack platforms has disrupted and suppressed launch operations. The effort in this project was to quantify these effects. Currently a technical report is in progress on the results of this research.

FORECASTING THE CONDITIONAL DELAYED ENTRY PROGRAM LOSS PROBABILITIES FOR THE OPTIMAL MISSIONING MODEL

Paul R. Milch, Professor
Lyn R. Whitaker, Associate Professor
Department of Operations Research
Sponsor: U.S. Army Recruiting Command

OBJECTIVE: The goal of this project is to devise a method of estimation of the number of losses (and accessions) from the Delayed Entry Program (DEP).

SUMMARY: Computer programs were prepared in APL to compute: 1) the estimate of the conditional probability of accessions/losses from the DEP given length of stay so far, by mission box and contracted DEP length from a set of closed records; and 2) the number of open records on a specified date, by mission box and contracted DEP length. Combining the above two quantities, future numbers of accessions/losses in the next several months were forecasted by mission box and contracted DEP length. Forecasts made by the above procedure were compared to actual accessions/losses using a DEP data file of records over the fiscal years 1988 through 1995 and the accuracy of the forecasts expressed in percentage terms.

Although the accuracy of the forecasts was acceptable over entire *yearly* periods in most cases, the *monthly* forecasts were often highly inaccurate. Closer examination indicated that the reason for this inaccuracy is the seasonal nature of losses. Whereas the procedure outlined above lumped all data together in the estimation of conditional probabilities, it appears that individuals contracting during the winter quarter may behave quite differently from those contracting during the other quarters. It is therefore suggested that future accession/loss forecasting efforts concentrate on separating data by quarters and proceed with the estimation procedure that way.

THESIS DIRECTED:

Lukasiewicz, C.E., CAPT, USA, "The Delayed Entry Program's Effects on Limited Entry Training Attrition," Master's Thesis, March 1995.

OTHER:

Milch, P.R. and Whitaker, L.R., "Forecasting Future Accessions from the U.S. Army's Delayed Entry Program," Naval Postgraduate School Technical Report, forthcoming in 1996.

OPERATIONS RESEARCH

DELAYED ENTRY PROGRAM ACCESSION MISSION MODEL
Paul R. Milch, Professor
Department of Operations Research
Sponsor: U.S. Army Recruiting Command (USAREC)

OBJECTIVE: Under mutual agreement with sponsor, this project was redirected with the new title "Forecasting Delayed Entry Program (DEP) Accessions/Losses at the Battalion Level." The new objective is to forecast accessions/losses from the DEP at the battalion level.

SUMMARY: Principle investigator visited USAREC in October 1995 to work out details of the new project objectives. Request for new battalion level data was fulfilled in December 1995 and project has progressed since then to process the new information and work out details of the forecasting procedure at the battalion level. Attempts are made to take into account seasonality of losses suggested by earlier research results.

DOD KEY TECHNOLOGY AREAS: Computing and Software, Manpower, Personnel and Training

KEYWORDS: Delayed Entry, loss rates, seasonal losses, battalion level

CONTINUED DEVELOPMENT OF MEASURES OF EFFECTIVENESS
FOR THE UNIVERSAL JOINT TASK LIST
Sam H. Parry, Professor
Department of Operations Research
Sponsor: Defense Manpower Data Center

OBJECTIVE: This continuing research effort develops a methodology for evaluating tasks performed by a joint staff as set forth in the Universal Joint Task List (UJTL). Measures of effectiveness (MOEs) are defined for several functional areas. Automated data collection procedures from the Joint Theater Level Simulation (JTLS) are implemented, with emphasis on providing the staff planner with an ability to associate causal reasons for significant events in an actual CINC exercise.

SUMMARY: The Universal Joint Task List, a supplement to the Joint Training Manual, is a comprehensive listing of all joint tasks pertaining to the Armed Forces of the United States. Tasks are defined as they relate to the strategic, operational, and tactical levels of war. This research, initiated in October, 1994, develops an exercise analysis methodology for evaluating CINC staff performance in the execution of joint tasks during the conduct of a Computer Aided Exercise (CAX). Research during CY 1995 resulted in analysis of data from JTLS runs for the sustainment and intelligence strategic tasks which demonstrated the usefulness of the developed methodology. Initiated in July, 1995, current thesis research by six NPS students is focused on the areas of ground maneuver forces, protection of high value assets (both land and sea based), prosecution of enemy high value targets, amphibious operations, and force deployment. Results from INTERNAL LOOK 96, a USCENTCOM exercise in March, 1996, and three weeks of controlled experimental runs using JTLS will provide the data for demonstrating developed methodologies.

PUBLICATION:

Combs, R., Parry, S., and Towery, C., "Development and Implementation of Measures of Effectiveness for the Universal Joint Task List in the Joint Theater Level Simulation," Proceedings of Winter Simulation Conference, Washington, DC, 3-6 December 1995.

OPERATIONS RESEARCH

CONFERENCE PRESENTATIONS:

Combs, R., Parry, S., and Towery, C., "Development and Implementation of Measures of Effectiveness for the Universal Joint Task List in the Joint Theater Level Simulation,"Winter Simulation Conference, Washington, DC, 3-6 December 1995.

Parry, S., "Use of a Computer Aided Exercise to Evaluate CINC Staff Training Based on the Universal Joint Task List," JMETL Conference, US Naval Doctrine Command, Norfolk, VA, 19 September 1995.

THESES DIRECTED:

Combs, R.A., "A Methodology for Evaluating Execution of Universal Joint Tasks Within the Context of a Computer-Aided Exercise," Master's Thesis, September 1995.

Towery, C.R., "A Methodology for Evaluating the Performance of Intelligence Functions During a Computer-Aided Exercise," Master's Thesis, September 1995.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Joint missions, measures, training evaluation

COMBATANT LOGISTICS COMMAND AND CONTROL
David A. Schrady, Professor
Department of Operations Research
Sponsor: Naval Postgraduate School - Institute of Joint Warfare Analysis

OBJECTIVE: The objective of this work is to identify the requirement for a continuous logistics assessment, a logistics picture, for the joint warfare commander encompassing all the forces under his command.

SUMMARY: The observation was made that had Iraqi forces crossed the border into northeastern Saudi Arabia in September of October 1990, General Schwartzkopf would have needed to know the logistics status of all CENTCOM forces in order to evaluate his alternatives for dealing with this situation. CENTCOM forces consisted of units of the four U.S. armed services and, eventually, those of the coalition allies. JCS Logistics Doctrine says that "to exercise control at the strategic, operational and tactical level of war, commanders must also exercise control over logistics." Looking in detail at logistics in the Gulf War, it was argued that CENTCOM had no comprehensive logistics assessment capability. With reference to the current "revolution in military affairs", it was argued that there will be no revolution in military logistics unless logistics is recognized as worthy of and requiring access to modern information, communication and command and control technologies. This effort was not completed in 1995, but an extensive draft report has been written.

THESIS DIRECTED:

Plunk, C.D., "A Computer Simulation of Logistics Networks," Master Thesis, March 1995.

DOD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Logistics, command and control, CENTCOM

OPERATIONS RESEARCH

READINESS ASSESSMENT
David A. Schrady, Professor
Department of Operations Research
Sponsor: Unfunded

OBJECTIVE: This work, though unfunded, relates to the NPS Institute of Joint Warfare Analysis and the Joint Warfighting Capabilities Assessment area of Joint Readiness. The objective was to understand the subject at a level which would allow NPS to dialogue with the principals.

SUMMARY: A discussion group consisting primarily of military faculty members and the investigator was formed and met periodically for 6-7 months. Literature was identified and discussed. It came to be understood that while readiness is a commonly used concept, it lacks definition. Using statistical regression as a conceptual model, one cannot talk about the indicators which best predict readiness when there is no definition or independent measurement of readiness. Thus readiness is de facto defined in terms of the indicators selected. This results in there being hundreds (at least) definitions of readiness, readiness being subjected to politization, and military readiness being a subject difficult to communicate to the Congress or the public. The U.S. Economy was identified as another complex subject about which there is widespread interest and for which predictive capability is desired. The state of the domestic economy cannot be described by a single measure, but a number of measures (more than 40) have been sanctioned by the Government to describe the state of the economy. These are the economic indices and most of them only track aspects of the economy and do not try to predict future states of the economy. Nonetheless the economic indices seem to be of real value to policy makers, corporations and individuals through their ability to provide baselines and trends. It is concluded that such Government sanctioned indices for military readiness would be most useful and the form of a number of such indices were suggested. This has been briefed to the DUSD(Personnel and Readiness) and his staff.

CONFERENCE PRESENTATION:

Schrady, D.A., "Joint Readiness Assessment," International Symposium on Military Operational Research, Shrivenham, UK, 5 September 1995.

DOD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Military readiness, joint readiness, readiness assessment

STRATEGIC SEALIFT PROTECTION
David A. Schrady, Professor
Department of Operations Research
Sponsor: Unfunded

OBJECTIVE: This work, though unfunded, relates to the NPS Institute of Joint Warfare Analysis and the Joint Warfighting Capabilities Assessment area of Strategic Mobility and its Protection. The objective was to characterize the need for naval units to provide protection for sealift in support of a future Major Regional Contingency (MRC) and to gauge the impact of this requirement on the shrinking number of Navy surface combatant ships.

SUMMARY: The study focused on quantifying the impact of sealift protection on the Navy's available number of surface combatants, i.e., will there be surface combatants available for sealift protection in a future MRC in which sealift protection is required for some part of the transit into the theater. Two MRC scenarios were studied (Southwest Asia and Korea) and the threat to shipping in each scenario was characterized using unclassified sources. The 1987-88 tanker escort operations in the Persian Gulf (Operation Earnest Will) were studied to understand the types of naval capabilities needed for sealift protection. The Bottom Up Review MRC Building Block (of forces) was used to loosely estimate

the non-sealift protection demands for surface combatants. The sealift shipping stream of the Gulf War was used to estimate sealift protection requirements. How this requirement depends on convoy distance and speed, sealift ship off-load time, and the maximum sealift ship delay time for convoy formation purposes were examined. Finally the Navy surface combatant ship sealift protection required numbers were characterized. The results appear in an NPS IJWA technical report.

PUBLICATION:

Schrady, D.A., Olsen, C.I., and Redman, T.L., "Strategic Sealift Protection," Naval Postgraduate School Technical Report, NPS-IJWA-95-001, June 1995.

DOD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Sealift protection, escort, strategic mobility

TACLOGS: TACTICAL LOGISTICS SUPPORT SYSTEM
David A. Schrady, Professor
Department of Operations Research
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The objective of this continuing project is the creation of a tactical logistics support system for a battle group or battle force and to incorporate the support system in the Navy Tactical Command System - Afloat (NTCS-A) within the Joint Maritime Command Information System (JMCIS).

SUMMARY: Building from a stand-alone, PC-based prototype system which was successfully employed in a number of Commander Second Fleet exercises, development has restructured and extended the ideas of the prototype for operation with the Navy standard TAC-3 or TAC-4 workstations as an application (tactical decision aid) within the Joint Maritime Command Information System . Initial development was completed in CY94. Testing and problem resolution were accomplished this year, culminating in the first at-sea testing of TACLOGS in the Commander Second Fleet exercise JTFX 96-1 in December 1995. TACLOGS was installed on the JMCIS system of the command ship, USS Mount Whitney, and was used throughout the exercise in the Joint Operations Center.

DOD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Naval Logistics, operational logistics, battle group sustainability

MIXED MINEFIELD ANALYSIS
Alan Washburn, Professor
Department of Operations Research
Sponsor: Navy Tactical Support Activity

OBJECTIVE: Develop a computationally and operationally feasible framework for a tactical decision aid for minesweeping in minefields where a variety of mines are present.

SUMMARY: A prototype tactical decision aid MIXER was developed. MIXER evaluates a given minesweeping plan by Monte Carlo simulation, including losses of minesweeping vehicles and gear. MIXER will also provide approximately optimal minesweeping plans. Software was delivered to the financial sponsor and also to COMMINEWARCOM, the tactical sponsor.

PUBLICATION:

Washburn, A., "MIXER: A TDA for Mixed Minefield Clearance," Naval Postgraduate School Project Report, NPS-OR-95-011PR, September 1995.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Minefield, minesweeping, decision

ICEBERG DENSITY FORECASTS
Alan Washburn, Professor
Department of Operations Research
Sponsor: U.S. Coast Guard

OBJECTIVE: International Ice Patrol (IIP) products currently include maps of icebergs, radar targets, and growlers within the Limits of All Known Ice (LAKI). The position of each iceberg at a given time is obtained by tracking it from its last known position using a drift model. These maps are useful in ship routing, but do not give any graphical indication of the uncertainty of position for each iceberg, which must necessarily be large if the iceberg has not been seen for some time, nor do they give any information about icebergs that have never been seen by IIP. Both of these missing aspects are potentially important in routing ships to avoid icebergs. The purpose of this research is to describe how to include these aspects in a new kind of graphical output that could be of use in planning IIP flights, as well as in ship routing.

SUMMARY: The IIP drift model was extended to calculate probability of detection for any iceberg track, based on IIP's flight records. By applying the model to a simulated population of icebergs, the density of undetected icebergs can be estimated and displayed. A computer program ICEBRG that accomplishes these tasks was delivered to IIP.

PUBLICATION:

Washburn, A., "The ICEBRG Detection Model," Naval Postgraduate School Project Report, NPS-OR-95-004PR, May 1995.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Iceberg, ice, detection

SAMPLING PLAN AND ANALYSIS FOR INSPECTING AIRCRAFT CARRIER TANKS AND VOIDS
Lyn R. Whitaker, Associate Professor
Department of Operations Research
Sponsor: Naval Sea Systems Command Detachment

OBJECTIVE: Aircraft carriers have over 1,000 tanks and voids. Corrosion within these tanks can have devastating safety and environmental effects. Inspecting these tank and voids is often very costly and dangerous. Failing to identify tanks that have deteriorated, so that their maintenance is unplanned growth work or new work or so that they are not maintained is even more costly. In the past the tanks and voids that tend to be inspected are the ones that have been opened for maintenance or repair work or because they are more accessible. This can lead to a distorted view of the condition of similar unopened tanks and voids. The purpose of this work is to first develop sampling plans to open and

inspect tanks and voids in such a way that an unbiased view of the overall condition of like tanks and voids can be inferred. Subsequent sampling plans will use this information to inspect so that tanks and voids needing work can be identified early for planning purposes.

SUMMARY: This is a continuing project. The approach taken in this research is to have sampling plans ready for each carrier as it comes into availability. Thus, we start with simple plans and adapt them as we learn more about the condition of tanks and voids, their deterioration in an operating environment, and a historical profile of tanks are built. This past years efforts have focused on assessing the current condition of tanks and voids. We have provided a sampling plan which identified over a 110 tanks and voids to be opened and inspected for CVN-72 (Abraham Lincoln). This sampling plan was based on simple random sampling of tanks and voids stratified into four major groups. The first year of the plan is now being implemented. As part of his thesis, Lt. Mark Thornell refined the approach taken on the CVN-72. He grouped tanks and voids by function and location and developed a scoring system for the operational impact of tank or void failure. Based on this new stratification, the sampling plan for the Theodore Roosevelt, CVN-71 was developed and is now being implemented. Inspection data from the CVN-71 and CVN-72 generated from these plans as well the lessons learned from the actual implementation of sampling are being used to provide guidance for the next iteration of sampling on the CVN-71 and CVN-72. Lt. Thornell also devised a plan to compare a subset of the tanks and voids on the CV-63 and CV-64. Although, this project was not part of the previous proposal, the data gained will help provide an unbiased view of the conditions of tanks and voids on like non nuclear ships and should prove useful.

CONFERENCE PRESENTATION:

Whitaker, L.R., "Sampling Tanks and Voids for CVN-72," TVIP Maintenance Requirements Definition Conference, Norfolk, VA, 26 October 1995.

OTHER:

We have been active participants in the Tank and Void Inspection Program Working Group. We attended the first meeting of this group in Bremerton, WA, 5 April 1995. We have also briefed NAVAIR's Tank and Void Working

Group at 03Y in Crystal City 20 August, 1995. This research is supporting an experience tour for Lt Mark Thornell's master's thesis in Operations Research.

DOD KEY TECHNOLOGY AREA: Other (Safety and Environment)

KEYWORDS: Maintenance, inspection, sampling

AIRCRAFT ENGINE PERFORMANCE IMPROVEMENT
Walter M. Woods, Professor
Department of Operations Research
Sponsor: Naval Air Systems Command

OBJECTIVE: The objective of this project was to analyze performance data for fielded TF34 aircraft engines using the NALDA data base and develop performance improvement goals.

SUMMARY: Methods were developed for cleansing the TF34 engine data base so that meaningful estimates of engine performance parameters could be obtain that account for dependent relationships among engine failure times. Maintenance factors were identified that appear to contribute to low engine failure times. Parametric and non-parametric conditional survival probabilities were computed. Engine life times at which significant increase in wear-out occur where identified. Yearly trends in engine performance parameters for specific maintenance factors were developed. An integral equation was developed than can be used to solve for optimal no-build times for TF34 engines

relative to the hard inspection times of their components. This equation was developed to conform with concepts in the NAVAIR Reliability Centered Maintenance Program.

THESES DIRECTED:

Caudill, M.R., "Methods For Performance Goal Setting of Fielded Jet Engines," Master's Thesis, June 1995.

Malsbury, J.A., "Methods For Determining Goals and Expectations For Fielded Jet Engines," Master's Thesis, September 1995.

DOD KEY TECHNOLOGY AREA: Other (System Effectiveness)

KEYWORDS: Engine performance analysis, maintenance and reliability, system effectiveness

USING WEAROUT INFORMATION TO REDUCE RELIABILITY DEMONSTRATION TEST TIME
Walter M. Woods, Professor
Department of Operations Research
Sponsor: Unfunded

OBJECTIVE: Develop equations for upper and lower bounds on reduction in reliability demonstration testing when wearout information is used.

SUMMARY: The Weibull distribution is used to model the random time to failure of a device under time truncated reliability demonstration testing. If the shape parameter (() of the Weibull distribution is greater than 1, the device has a wearout feature. If (= 1, the device has no wearout. Equations are developed for computing the upper and lower bounds on the ratio of linear test times required to meet a given interval requirement on item reliability for given values of (> 1 compared with corresponding test times for (= 1.

PUBLICATIONS:

Woods, W.M., "Using Wearout Information to Reduce Reliability Demonstration Test Time," Naval Postgraduate School Technical Report, NPS-OR-95-016, December 1995.

Woods, W.M., "Using Wearout Information to Reduce Reliability Demonstration Test Time," Proceedings of U.S. Army Annual Conference on Applied Statistics, Adelphi, MD, 18-20 October 1995.

CONFERENCE PRESENTATIONS:

Woods, W.M., "Using Wearout Information to Reduce Reliability Demonstration Test Time," U.S. Army Annual Conference on Applied Statistics, Adelphi, MD, 18-20 October 1995.

Woods, W.M., "Reliability and Quality Assurance Topics Suitable For Presentation in Statistics Courses in Schools of Business," Tenth Annual Making Statistics More Effective in Schools of Business Conference, Sacramento, CA, May 1995.

DOD KEY TECHNOLOGY AREA: Other (System Effectiveness)

KEYWORDS: Reliability demonstration testing, wearout in testing

1995

Faculty Publications
and
Presentations

OPERATIONS RESEARCH

JOURNAL PAPERS

Almeida, R., Gaver, D.P., and Jacobs, P.A., "Simple Probability Models for Assessing the Value of Information in Defense Against Missile Attack," Naval Research Logistics, Vol.42, pp. 535-547, 1995.

Brown, G., Arntzen, B., Harrison, T., and Trafton, L., "Global Supply Chain Management at Digital Equipment Corporation," INTERFACES, Vol. 25, pp. 69-93, January-February 1995. (Nominated for the 1994 International Management Science Achievement Award) (35 minute videotape of 1994 International Management Science Achievement Award Competition, ORSA/TIMS Joint National Meeting, Boston, MA, April 24-27, 1994, College on the Practice of Management Science, Copyright 1994 and distributed by The Institute of Management Sciences, Providence, RI)

Brown, G., Bausch, D., and Ronen, D., "Consolidating and Dispatching Truck Shipments of Mobil Heavy Petroleum Products," INTERFACES, Vol. 25, pp. 1-17, March-April 1995.

Chakraborty, S. and Smyth, G.K., "A Stochastic Model for the Effect of Weather Conditions on Anthracnose Ggrowth in *Stylosanthes scabra*," Phytopathology, Vol. 143, pp. 495-499, 1995.

Dell, R.F., Rosenthal, R.E., and Baig, S., "Scheduling Peacetime Rotation of Pakistan Army Units," Naval Research Logistics, Vol. 42, pp. 1-13, 1995.

Gaver, D.P. and Jacobs, P.A., "Asymptotic Properties of Stochastic Greedy bin-packing," Communications in Statistics-Stochastic Models, Vol. 11, pp 333-348, 1995.

Hughes, W.P., Jr., "The Power In Doctrine," Naval War College Review, Summer 1995.

Hughes, W.P., Jr., "A Salvo Model of Warships in Missile Combat Used to Evaluate Their Staying Power," Naval Research Logistics, Vol. 42, No. 2, p. 267, March 1995

Hughes, W.P., Jr., "The Power in Doctrine," Naval War College Review, Vol. XLVIII, No. 3, p. 9, Summer 1995.

Hughes, W.P., Jr., Comment on Melton, Crawford and Hatton, "Fast Attack Craft in Littoral Warfare," Naval Institute Proceedings, Vol. 121 No. 5, p. 27, May 1995.

Hughes, W.P., Jr., "Fratricide and Littoral Warfare: Tactical Implication of Friendly Fire," Surface Warfare, Vol. 20, No. 2, p. 30, March/April 1995

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